DRAFT Kokanee (Sockeye) Salmon (*Oncorhynchus nerka*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
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Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult kokanee salmon and their justification are discussed below. The recommended tolerance values were developed in accordance with the "*DRAFT Methodology for Developing Thermal Tolerance Thresholds for Various Fish in Nevada – Juvenile and Adult, Summer*" (September 2015).

Chronic Thermal Tolerance Thresholds

Table 1 provides a summary of the range of chronic temperature tolerance values for kokanee salmon for various lines of evidence. These values are based upon a review of 7 papers and publications, the details of which are summarized in Attachment A.

There is obviously a wide range of temperatures from which to select an appropriate value and best professional judgment is called for. NDEP's approach is to accept the EPA recommendations from Brungs and Jones (1977) unless the literature review provides a compelling reason to utilize other values. EPA's chronic value of 18°C falls within the upper end of the range of potential criteria found in the literature, and is recommended as the chronic thermal tolerance level for adult/juvenile kokanee salmon. As discussed in the methodology, chronic temperature criteria are generally not set to ensure the most optimum conditions. In fact, Brungs and Jones (1977) recommends chronic criterion for a given fish species that is between the optimum temperature and the UUILT.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Optimal Growth Studies – Constant Temperature	
Optimum	8.9 – 15
Upper Optimum	17
Laboratory Optimum Swimming Performance Temperature	
Optimum	15 – 17.5
Upper Optimum	20.3
Laboratory Temperature Preference Studies	
Average Preferences	12 - 14
Laboratory Upper Temperature Avoidance Studies	15 - 18
Thresholds from EPA	18
Recommended Chronic Temperature Tolerance	**18**

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for kokanee salmon for various lines of evidence. These values are based upon a review of 5 papers and publications, the details of which are summarized in Attachment B.

For ease of presentation, the UILT values have been summarized by acclimation temperature ranges. However as discussed in the methodology document, only the UILT values for acclimation temperature near the recommended chronic criterion (18°C) are to be included in the acute criterion development process. For kokanee salmon, UILT values for acclimation temperatures 15 – 20°C are utilized for criterion development.

Table 2. Summary of Acute Temperature Tolerances

Category	Temperature Tolerances (°C)	Potential Acute Criteria (°C)
Laboratory Lethal Studies – UILT/UUILT		
UILT		
Acclim. = 5 – 10°C	22.2 – 23.5	
Acclim. = 10 – 15°C	22.0 – 24.4	
Acclim. = 15 – 20°C	22.5 – 24.8	20.5 – 22.8[1]
Acclim. = 20 – 25°C	23.5 – 24.8	
UUILT	24.8	22.8[1]
Thresholds from EPA	22	
Recommended Acute Temperature Tolerance	**22**	

[1]UILT and UUILT values reduced by 2°C to provide 100% survival (see *Methodology*)

A review of laboratory studies suggest that an appropriate acute criteria should fall between 20.5 and 22.8°C. NDEP's approach is to accept the EPA recommendations from Brungs and Jones (1977) unless the literature review provides a compelling reason to utilize another value. EPA's acute value of 22°C falls within the upper end of the range of potential criteria found in the literature, and is recommended as the acute thermal tolerance level for adult/juvenile kokanee salmon.

References

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ATTACHMENT A
Detailed Summary of Chronic Thermal Tolerance Values for Kokanee Salmon, Juvenile and Adult, Summer

Table A-1. Chronic Temperature Tolerances – Laboratory Optimal Growth Studies

Reference	Age or Size	Acclim. Temp. (°C)	Optimum Growth Temperature		Upper Optimum Growth Temperature	
			Temp. (°C)	Comment	Temp. (°C)	Comment
Brett et al. (1969)	Fingerling	7 – 12	15		17	Temperatures from 5 – 17°C are most favorable for young sockeye on the basis of growth and food-conversion efficiency.
Brett (1971)	Unknown		15		17	Maximum food-intake shows an optimum broadly related around an apex at about 17°C.
Donaldson and Foster (1941)	Fingerling		8.9 – 10			

Table A-1a. Chronic Temperature Tolerances – Laboratory Temperature of Optimum Swimming Performance

Reference	Age or Size	Acclim. Temp. (°C)	Temperature of Optimum Swimming Performance		Upper Temperature of Optimum Swimming Performance	
			Temp. (°C)	Comment	Temp. (°C)	Comment
Brett (1967)	Yearling		15			
Lee et al. (2003)	Adult		15 – 17.5		20.3	

Table A-2. Chronic Temperature Tolerances – Laboratory Preference Studies

Reference	Age or Size	Acclim. Temp. (°C)	Average Preference Temperature		Upper Preference Temperature		Final Preferendum	
			Temp. (°C)	Comment	Temp. (°C)	Comment	Temp. (°C)	Comment
Brett (1952)	Fry	5 – 23	12 – 14					

Table A-3. Chronic Temperature Tolerances – Laboratory Upper Temperature Avoidance Studies

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Brett (1952)	Fry	5 – 23	15	
Brett (1971)			18	Natural occurrence is limited in time and space at temperatures above 18°C despite being able to tolerate 24°C.

Table A-4. Chronic Temperature Tolerances – EPA

Reference	Temperature (°C)	Comments
EPA (1977)	18	Recommended level as MWAT

ATTACHMENT B
Detailed Summary of Acute Thermal Tolerance Values for Kokanee Salmon, Juvenile and Adult, Summer

Table B-1. Acute Temperature Tolerances – Laboratory Lethal Temperatures, UILT/UUILT

Reference	Size or Age	Acclim. Temp. (°C)	Test Duration	UILT		UUILT	
				Temp. (°C)	Comment	Temp. (°C)	Comment
Black (1953)	Fry	11	24-hour	22			
Brett (1952)	Fry	5		22.2		24.8	
		10		23.4			
		15		24.4			
		20		24.8			
		23		24.8			
Brungs and Jones (1977); McConnell and Blahm (1970)[1]	Juvenile (67 mm avg.)	10		22.5			
		20		23.5			
	Juvenile (100 – 105 mm)	10		23.5			
		12		23.5			
		15.5		22.5			
		17		23.5			
Servizi and Jensen (1977)	Adult	15.8 – 18.3		24			

[1]UILT values estimated by Brungs and Jones (1977) based upon test results from McConnell and Blahm (1970).

Table B-2. Acute Temperature Tolerances – Other Laboratory Studies

Reference	Temperature (°C)	Comments
Brett (1971)	24	Appetite is completely inhibited at 24°C. Growth is completely blocked at 24°C.

Table B-3. Acute Temperature Tolerances – EPA and Colorado

Reference	Temperature (°C)	Comments
EPA (1977)	22	No metric (DM, MWMT, etc.) recommended